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# **Universal Service Obligation and Loyalty Effects: An Agent-Based Modelling Approach**

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## Universal Service Obligation and Loyalty Effects: An Agent-Based Modelling Approach

by

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### *Abstract*

In network industries, a Universal Service Obligation (USO) is often seen as a burden on an incumbent, which requires compensation for the net cost of such service provision. This paper estimates the effects of consumer loyalty as an intangible benefit of USO in the postal sector. In doing so, the agent-based modelling (ABM) approach is applied, which makes it possible to model the behaviour of boundedly rational consumers and is thus particularly appropriate for taking into account intangibles considerations. The analysis shows that loyalty is crucial to whether the USO uniform pricing constraint results in loss-making or profitability. Under certain conditions and in the presence of a loyalty parameter, uniform pricing gives a USO provider an advantage, when the size of the rural area is sufficiently big and a disadvantage, if its size is too small. This finding is counterintuitive as USO providers in countries with sparsely populated areas are typically expected to incur a significant net cost of USO.

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\* The authors are officials at the European Commission in Brussels. The expressed views are strictly their own. We thank two anonymous referees for their comments.

## Résumé

L'obligation de service universel (USO) est souvent perçue par les industries de réseau comme un charge sur le fournisseur historique ce qui nécessite une compensation pour le coût net d'un tel fourniture de service. Cet article évalue les effets de la fidélité des consommateurs comme un avantage intangible de l'USO dans le secteur postal. Par cela, la modélisation multi-agents (GPA) est appliquée, ce qui permet de modéliser le comportement des consommateurs à rationalité limitée et qui est donc particulièrement approprié pour la prise en compte des considérations intangibles. L'analyse montre que la fidélité est essentielle pour savoir si la contrainte de prix uniforme de l'USO aboutit à la perte de décision ou de rentabilité. Sous certaines conditions et en présence d'un paramètre de fidélité, la tarification uniforme donne à un fournisseur de l'USO un avantage, lorsque la taille de la zone rurale est suffisamment grande et un inconvénient, lorsque sa taille est trop petite. Ce résultat est contre-intuitif, car on attend généralement que les fournisseurs de l'USO dans les pays ayant des zones peu peuplées encourrent un coût net important de l'USO.

**Classifications and key words:** agent-based modelling; liberalisation of the postal markets; postal sector; Universal Service Obligation (USO); USO provider.

## I. Introduction

A Universal Service Obligation (hereafter, USO) is often seen as a burden on an incumbent, which requires compensation for the net cost of such service provision. The question of the net cost of USO is relevant to all network industries, but the debate is at its most heated when discussing the postal sector. This is because the provision of postal services in sparsely populated areas – often combined with high delivery frequency – is typically seen as a significant cost for the operator as opposed to its overall revenues. The gradual phasing out of letter weight-based reserved areas was motivated by the perceived net cost of USO. Such monopoly rents were seen as a necessary, albeit implicit, form of subsidy for the cost of USO. With the liberalisation of the postal markets, this mechanism was replaced by a right for USO providers to (e)mail an invoice for the net cost of this service to the relevant regulator, seeking its review and, eventually, due compensation<sup>1</sup>. The significance of USO costs in the sector is lately exacerbated by decline in postal demand, largely due to the increasing use of electronic communication.

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<sup>1</sup> See specifically art. 7 and Annex I of Directive 2008/6/EC (3<sup>rd</sup> Postal Directive). These solutions bear strong resemblance to corresponding sections in Directive 97/33/EC and 2002/22/EC in the electronic communications sector.

Academic literature has traditionally focused on the issue of cost allocation between USO and the remaining ‘commercial’ services of a USO provider<sup>2</sup>, placing lesser emphasis on the calculation of the benefits of USO to the incumbent<sup>3</sup>. Barkatullah (2002) et al and London Economics (2002) speak of demand complementarities (between USO and non-USO or even non-postal products) as a benefit of USO. In the same study, London Economics (2002) analyses economies of scale and scope for a multiproduct USO provider. In order to account for the benefits of USO on the supply side, another approach associates a monetary value with intangible assets such as: the commercial value of advertising space on postal outlets and fleets (Postcomm, 2001); contingent valuation/surveying of the value of a USO provider’s brand; corporate reputation in general (Burns et al, 2002).

The uniform pricing requirement – often an explicit component of USO – is rarely discussed in the context of USO benefits. Instead, it is seen as a burden imposed on the incumbent that facilitates selective entry (‘cherry-picking’) by new operators. ‘Menu costs’, and the related lowering of transaction costs, are the only mechanism through which uniform pricing has been considered as a USO benefit so far (London Economics, 2002).

In this paper, uniform pricing plays a role in terms of loyalty and for that reason can also be also hypothesised as an intangible benefit of USO. The analysis will commence with the presentation of the reasons for choosing the agent-based modelling approach for this analysis followed by an overview of its specification. The paper will continue on to present its main results and conclude, in the last section, with regulatory implications and suggestions for future research.

## II. Choice of methodology

Agent-based modelling (hereafter, ABM) is a relatively new approach to the simulation of complex systems. Agent-based modelling has a unique and very useful feature – instead of investigating the dynamics of an entire system, it assumes the perspective of its individual agents. It then studies the results

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<sup>2</sup> See, for instance: M. Cigno, D. Monaco, E. Pearsall, *An Operational Measure of the Cost of Universal Service as a Cross-subsidy*, in Heightening Competition in the Postal and Delivery Sector, 2010 or Ch. Jagg, M. Koller, U. Trinker, *Calculating the Cost of the Universal Service Obligation: the Need for a Global Approach*, in Progress in the Competitive Agenda in the Postal and Delivery Sector, 2009.

<sup>3</sup> Strictly speaking, USO does not have to be vested with the incumbent but so far postal USO has never been offered to a new entrant or even put up for a tender in any EU member state.

of their interactions that often cannot be analytically inferred from individual behavioural rules<sup>4</sup>. The starting point of an ABM simulation is defined as: the agents and theory of their behaviour; the rules governing the relationships and interactions between agents and; agent-related parameters (Macal and North, 2005).

When applied to social sciences, agents usually represent people or groups of people (e.g. firms or regulatory bodies). Formally, agents are described by means of their attributes which include: personal characteristics, location, or preferences and behaviours (i.e. decision-making algorithms). Among the advantages of ABM lies the fact that agents do not need to be defined as rational or to possess 'representative' characteristics, as is the case in traditional equilibrium-based modelling approaches. Agent-based modelling simulations are characterised by their flexibility because attributes and behaviours may vary across agents within the same model, as well as change during the simulation as a result of a 'learning process'.

Recent advances in computer science made ABM a powerful tool for simulations and forecasts, with direct applications in network industries<sup>5</sup>. Telecommunications and postal markets are promising fields for the use of ABM given, on the one hand, their complexity and on-going structural changes and, on the other hand, important regulatory implications of their analysis. The postal sector, in particular, has traditionally been monopolised and was only very recently opened to competition. To date, there is not enough reliable empirical data for a traditional economic analysis, as there is limited market entry and hardly any competition in the provision of USO products. Postal markets are also highly dependent on individual preferences, network effects and interactions, making simulations one of the suitable tools for making predictions and reasoning ex-ante regulatory decisions. Another reason for applying ABM in this context is that intangible benefits are inherently difficult to capture with standard analytical tools such as account calculations, for example, or equilibrium-based economic models.

In this paper, the ABM method is applied to analyse the relationship between USO and profitability in a postal market open to competition. For that purposes, focus is placed on the demand side of the market, which eventually determines market shares and profitability of postal operators. The agents considered here represent a population of consumers defined by: their location (urban or rural area); the operator currently used (Incumbent or Entrant); loyalty to the current operator; price elasticity and; accumulated

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<sup>4</sup> Behaviour resulting from a series of individual interactions is referred to as 'emergent'.

<sup>5</sup> For example, EMCAS, a large-scale simulation model of the electric power market, was designed and used for regulatory purposes by the Illinois Commerce Commission (Cirillo et al., 2006).

past utility with each of the operators, remembered for a certain number of individual time periods (e.g. months). The flexibility of ABM makes it possible to assume that consumers are boundedly rational and not perfectly informed – present decisions are based on past experiences with each of the operators. This assumed behaviour seems to reflect reality well. It would be unrealistic to assume that postal consumers are perfectly informed of existing postage prices or can calculate them as a function of location of their recipients, and that they solve an optimisation problem each time they send a piece of mail.

### III. Model specification

A stylised model of competition in the postal sector is applied here, with an Incumbent initially serving the whole market and an Entrant competing for market share. The market is assumed to be geographically divided into two broad segments, called for simplicity, ‘urban’ (with lower costs of service provision) and ‘rural’ (with higher costs). The cost structure and the proportion of each segment in the total market (by number of consumers) are known. Both operators are in principle able to deliver throughout the entire geographical market. The cost functions are assumed to be identical for both operators.

For the purpose of this analysis, only one stylised type of mail is considered and service quality is assumed to be identical for both operators. From the point of view of consumers, the services provided by the two competing operators are thus only different in terms of price.

The Incumbent is assumed to be the ‘Universal Service Provider’, i.e. guaranteeing the provision of postal services of a certain pre-defined quality throughout the entire geographical area. Additionally, the obligation is assumed to include uniform pricing, i.e. the same price of delivery to the rural and to the urban area. By contrast, the Entrant is not bound by uniform pricing, a fact which seems to immediately provide him with a competitive advantage.

Nevertheless, this model takes into account the effect on market outcomes of consumer ‘loyalty’. It is assumed here that consumers are boundedly rational and do not solve the standard optimisation problem each time they use postal services. Instead, they remember their past utilities, obtained with each of the operators, for a certain time period (e.g. several months) and base their current decisions on these accumulated experiences. As shown below, this assumption alone can significantly change the results achieved by the two postal operators both in terms of market share and profit.

It needs to be noted that ‘loyalty’ is not understood here as a fixed preference for a given brand but as a tendency to consistently use the same postal operator, changing over time and resulting from positive experiences with its services accumulated in the past. Moreover, to reflect reality better, some randomness is introduced in determining customer preferences, i.e. a service provider may occasionally be chosen by chance, even if the other operator performed better in the past. Additionally, ‘loyalty’ is fully symmetric between the Incumbent and the Entrant, i.e. both can profit from the decision-making inertia of consumers.

At the beginning of each time period (e.g. each month), consumers send mail to each other with a certain predefined probability. Mail can be sent to ‘urban’ or ‘rural’ areas, with probabilities depending on the proportion of recipients living therein. Consumers choose a postal operator each time according to the following rules:

- At the beginning of period 1, all consumers are served by the Incumbent.
- At the end of each subsequent period  $i$ , consumers calculate their utility from the postal service (if they used it), which is:

$$U_i^I = r - p^I,$$

if the consumer is served by the Incumbent, and

$$U_i^E = pr^{Rural}(r - p^{ERural}) + (1 - pr^{Rural})(r - p^{EUrban}),$$

if the consumer is served by the Entrant, where:

- $r$  is a constant ensuring the ensuing utilities at least to equal the reservation utility of consumers;
- $p^I$  is the uniform price charged by the Incumbent;
- $p^{ERural}$  and  $p^{EUrban}$  are the prices charged by the Entrant in rural and urban areas respectively;
- $pr^{Rural}$  is the proportion of consumers living in the rural area.

In this model, two types of consumers are considered: those with zero price-elasticity who send mail every time they need to, irrespective of the price of such service and; the ‘price-elastic’ ones who can refrain from sending mail if they consider the price to be too high (above some pre-set reservation value). In reality, the latter category can be thought of as consumers having access to alternative means of delivery such as e-mail, for instance. In this simulation, the proportion of ‘price-elastic’ consumers is assumed to be quite high (70%).

The utility obtained from sending mail with either of the operators is remembered for a predefined number of periods (e.g. months), weighted according to how recent they were:

$$V_i^I = \sum_{k=1}^m \frac{1}{m-k+1} U_{i-m+k}^I$$

$$V_i^E = \sum_{k=1}^m \frac{1}{m-k+1} U_{i-m+k}^E$$

Here  $m$  is the pre-defined memory span of consumers;  $V_i^I$  and  $V_i^E$  are the accumulated utilities with the Incumbent or the Entrant for the last  $m$  periods up to period  $i$ . While  $i < m$ , only  $i$  past utilities are included.

At the beginning of each time period, consumers review their accumulated utilities and on this basis determine their 'loyalty' level to the current operator, that is, they 'calculate' the probability of switching to another operator. This probability is modelled here according to the logistic distribution density function. The logistic probability distribution was chosen as an approximation, widely used in social sciences, for example, to model the learning processes as well as many other aspects of human behaviour (e.g. Modis, 1992). After calibration, the density function parameters were fixed at  $\mu = 0$  and  $s = 3$ . However, these values are not restrictive in terms of the qualitative outcomes below. The probability of switching is:

$$L_i = \frac{1}{1 + e^{-\frac{x_i}{s}}},$$

where  $x_i$  is the difference between accumulated utilities obtained with the Incumbent and the Entrant in the last  $m$  periods, i.e.:

$$x_i = V_i^E - V_i^I,$$

if the Incumbent is currently used;

$$V_i^I - V_i^E,$$

if the Entrant is currently used.

If sending mail, consumers switch in period  $i + 1$  to another operator with probability  $L$  ( $1 - L$  is, therefore, consumers' loyalty to the current operator). The process continues for a certain number of periods (usually, several years), fixed in advance.

As for the price setting mechanism of postal operators, some bounded rationality is assumed to exist as well. Operators cannot solve the optimization problem for prices each and every time (as the demand function is unknown in



advance), they maximize profits locally by adjusting their prices in the ‘trial and error’ process. In fact, in order to benefit from the inertia in consumer loyalty, operators change prices with a certain delay. More precisely, at the beginning of the first period, both the Incumbent and the Entrant set their prices slightly above marginal costs of delivery. For the Incumbent, the price is uniform and is based on the average marginal cost between the rural and the urban area. In the subsequent periods, with a certain interval (e.g. every five periods in the simulations below), both operators review their prices and change them by a certain predefined amount. The direction of the change is determined by the previous results in terms of profit (profit is defined in a standard way and depends on total demand, prices and costs). If the average profit in the current interval is lower than the average profit in the previous interval, the direction of the change is reversed. Otherwise, both operators change their prices in the same direction as long as the profit is non-decreasing. Additionally, the Incumbent’s price is limited from above by the pre-set regulatory ceiling.

It is assumed here that the cost structure is as follows: service costs in the urban and the rural area are both fixed; they are higher in the rural area. Variable (per item) costs are higher for the rural area as well. These costs, as well as the initial values for delivery prices, were chosen arbitrarily on the assumption that only their relative values matter for the below outcomes.

Specifically, the following parameters were used in all the following simulations:

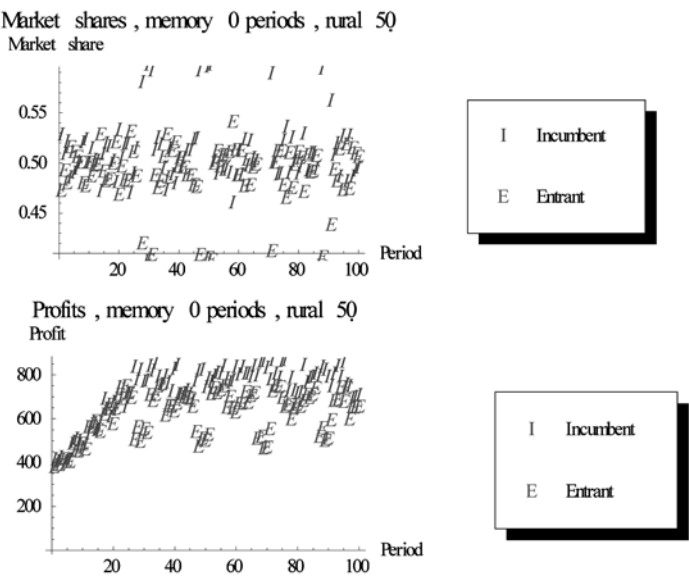
Parameter	Value
Population size	1000
Number of periods	100
Probability of sending mail in each period (equal for all consumers)	0.8
Proportion of ‘price-elastic’ consumers	0.7
Constant $r$ in the utility function of consumers	6
Fixed costs in the rural area	200
Fixed costs in the urban area	100
Variable per-item cost of delivery to the rural area	3
Variable per-item cost of delivery to the urban area	1
Incumbent’s uniform price start value	3
Entrant’s price in the rural area start value	4
Entrant’s price in the urban area start value	2
Reservation price for price-elastic consumers	5
Initial loyalty to the Incumbent	0.5
Step for price changes	0.2
Number of periods with unchanged price	5

**Figure 1.** Parameters used in the simulations.

It is clear that with the above starting prices, the Incumbent provides higher utility to consumers sending mail to the rural area. On the other hand, using the Entrant is beneficial when sending to the urban segment. Intuitively, given the assumptions of this model, this should form a positive perception of the Incumbent when consumers often send mail to the rural area. It follows that in terms of market share, the Incumbent benefits from the larger size of the rural area. This relationship is investigated in more detail below.

IV. Main results

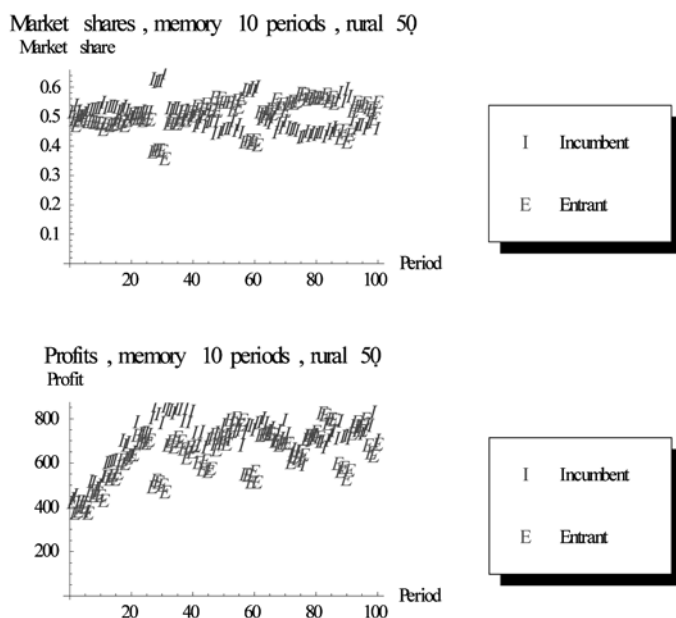
The results of the following simulation demonstrate these effects for the population of 1000 consumers, spanning 100 time periods (e.g. 100 months, meaning approximately eight years). At first, it is assumed that the rural segment occupies half of the geographical area to be served. To see the effect of consumer loyalty on market outcomes, it is first assumed that consumers are not able to remember their past experiences, that is, they are indifferent to the two operators at the beginning of each period. The simulation with a zero memory span results in the following distribution of market shares and profits:



**Figure 2.** Market shares and profits of postal operators when rural and urban areas are equal, and consumers' memory span is 0.

It can be immediately observed that the evolution of market shares in this case is totally random. This is explained by the fact that consumers make no reference to their past experiences when choosing which operator to use. Moreover, as at the beginning all consumers are served by the Incumbent and have little incentive to switch, the Incumbent tends to keep a higher market share and, with the assumed cost-price structure, tends to enjoy superior profits.

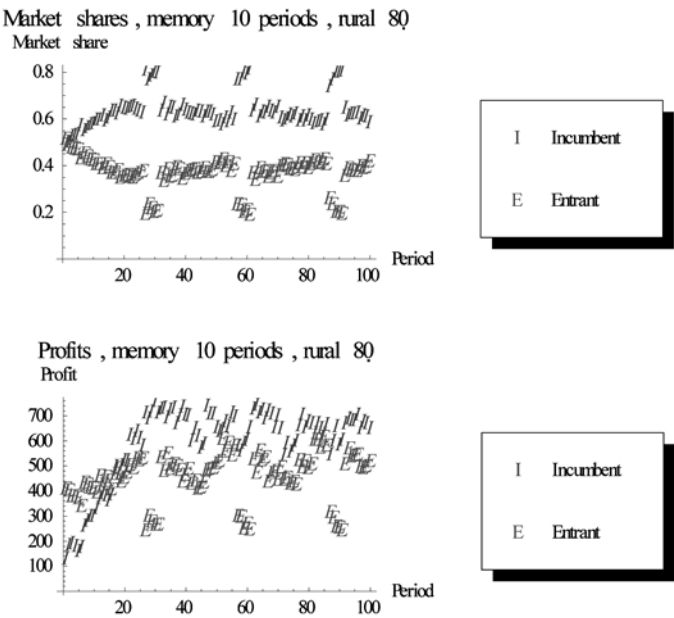
When consumer loyalty is introduced into the model but keeping the same geographical division, the situation does not change significantly. What happens, however, if it is assumed that consumers are able to memorise their experience for 10 subsequent periods? The simulation, with other parameters unchanged, now yields the following results:



**Figure 3.** Market shares and profits of postal operators when rural and urban areas are equal, and consumers' memory span is 10 periods.

Although market shares evolve more systematically in this model, the two operators tend to perform at the same level. Indeed, given that the Incumbent gives better service experiences in the rural area and the Entrant in the urban segment and that the two areas are of equal size, both operators provide on average the same experiences to their consumers, who are therefore equally loyal to both operators.

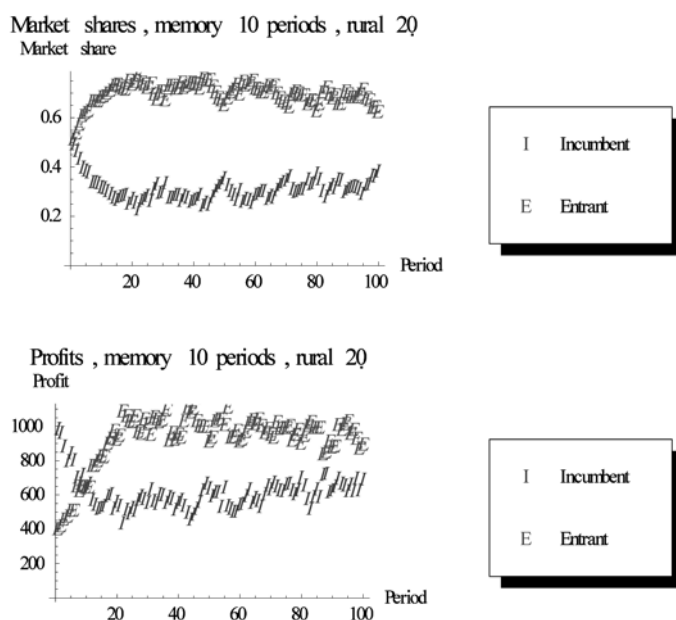
As discussed above, the scale of the importance of consumer loyalty changes, intuitively, depending on the respective size of the rural area. That relationship is investigated in more detail below. When the size of the rural area is relatively large, the Incumbent enjoys an obvious competitive advantage. For example, let's assume that the share of the rural area is 80% and the memory span of consumers is, as before, 10 time periods (e.g. months):



**Figure 4.** Market shares and profits of postal operators when rural area occupies 80%, and consumers’ memory span is 10 periods.

The outcome is now very different. The Incumbent gains a steadily superior market share and also enjoys, after a certain point (around 20 months), a significant advantage in terms of profits. Moreover, running several simulations with different parameters, it can be concluded that the Incumbent starts to enjoy some competitive advantage when consumers can only recall one period back, the exact effect depending on the simulation parameters including the importance associated by consumers with the last memorised utility.

Importantly, the above result is only due to the change in the size of the rural area. To stress this result, let's assume now that the proportion of the rural area is very small (20%). The situation reverses: the Incumbent clearly loses market share to the Entrant and faces a significant disadvantage in terms of profits:

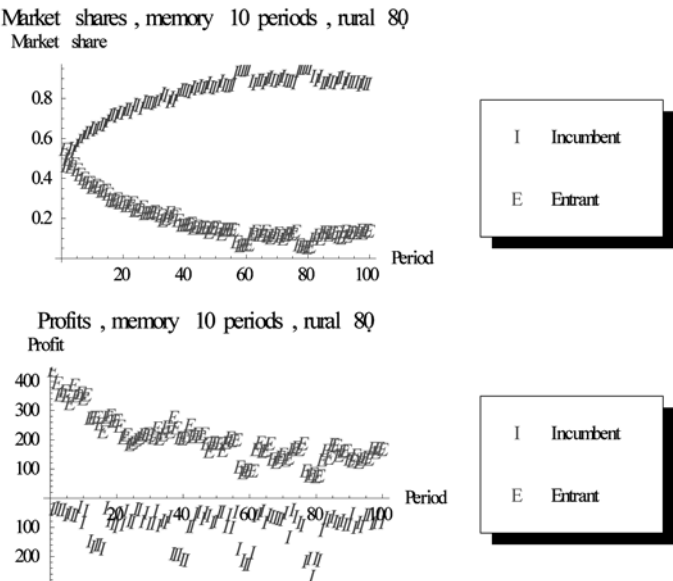


**Figure 5.** Market shares and profits of postal operators when rural area occupies 20%, and consumers' memory span is 10 periods.

The profits of the Incumbent eventually fall lower than those of the Entrant, although the urban segment (where the Incumbent's uniform price is higher than the Entrant's urban price), accounts for 80% of the market. As before, this is due to the loss in the Incumbent's market share, which occurs because the Entrant persistently performs better in the urban sector, which is very large in this simulation.

Although it is generally believed that the larger the loss-making segment, the greater the competitive disadvantage imposed by uniform pricing, the backward-looking nature of consumer demand may inverse this relationship in this model. The Incumbent enjoys a competitive advantage due to consumer loyalty unless the size of the rural area is too small, in which case the uniform price is a disadvantage.

It needs to be noted that the above simulations assumed that uniform prices allow the Incumbent to cover its marginal costs in both geographical areas. Restricting regulatory conditions further, what would happen, however, if the Incumbent is forced by the uniform price ceiling to serve both areas at its average marginal cost (i.e. at a loss, taking into account the fixed costs incurred)? Running the simulation with the rural area accounting for 80% of the market, the following results can be observed:

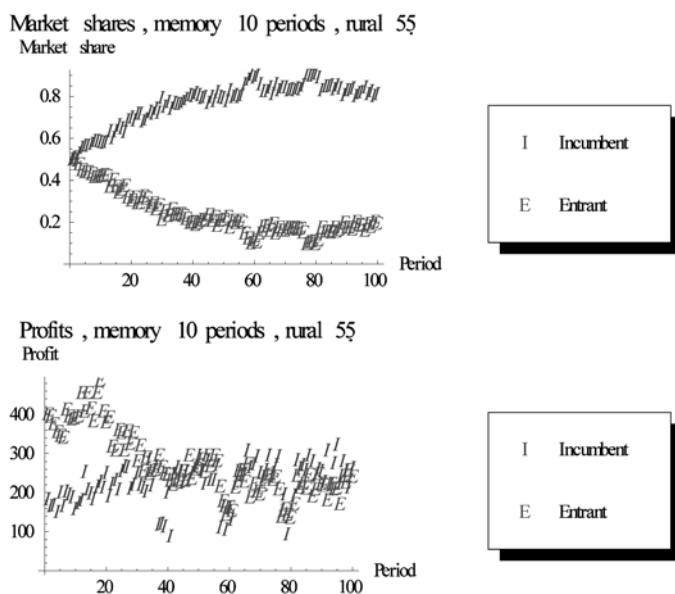


**Figure 6.** Market shares and profits of postal operators when rural area is 80% of the total, consumers’ memory span is 10 periods, and rural area is loss-making.

As before, the Incumbent’s market share is steadily increasing and eventually covers almost the entire market. However, the Incumbent is clearly suffering a loss in each period, due to serving a significant part of the market at a below-marginal-costs price. In this case, although advantageous for consumers who clearly prefer to be served by the Incumbent throughout the entire geographical area, uniform pricing hurts the Incumbent and needs to be compensated accordingly. Moreover, the Entrant who cannot compete on these restrictive terms eventually loses market share to the Incumbent and is forced out of the market. The total welfare effect of the uniform pricing in this case is, therefore, ambiguous, but most probably negative.

However, it is possible to find a size of the rural area that allows the Incumbent to do both: gain market share and enjoy positive economic results even under restrictive pricing conditions. For example, let’s assume that the size of the rural segment is 55% (Figure 7).

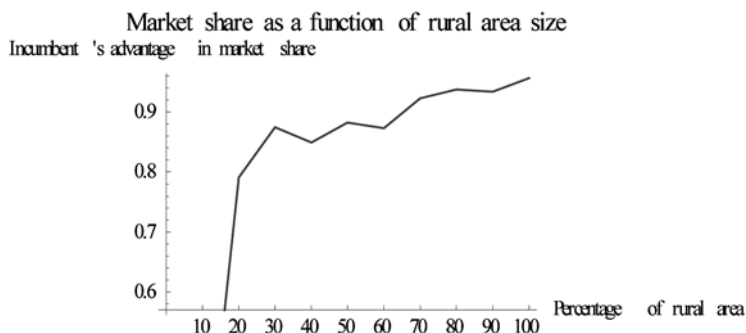
The rural segment is now big enough to allow the Incumbent to gain a significant market share without the rural area being too big, however, to hinder its profitability. At some point, the Incumbent’s profits become equal to, or even slightly higher, than those of the Entrant. In other words, a rural area of a particular size allows the Incumbent to have a competitive advantage due to consumer loyalty. However, as shown before, if the size of the rural segment



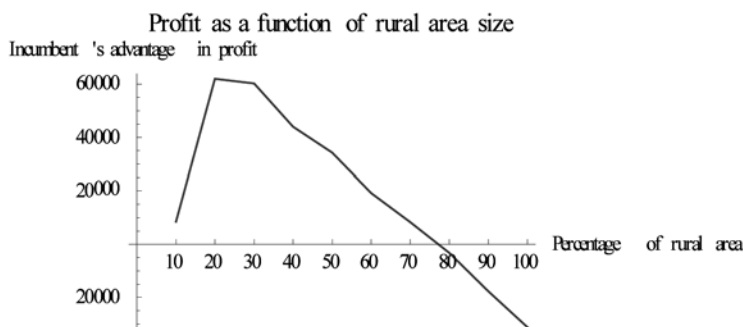
**Figure 7.** Market shares and profits of postal operators when rural area is 55% of the total, consumers' memory span is 10 periods, and rural area is loss-making.

increases, this advantage is compensated by the operational loss in the rural segment.

It is worth plotting this relationship for the parameters above and for the size of the rural area increasing from 0 to 100%. Figures 8 and 9 below show the Incumbent's advantage in terms of average market share and total profits over 100 time periods depending on the size of the rural area.



**Figure 8.** Incumbent's advantage over Entrant in terms of market share as a function of the rural area size.



**Figure 9.** Incumbent's advantage over Entrant in terms of total profit as a function of the rural area size.

In other words, even under restrictive pricing conditions, the loss-making segment does not constitute for the Incumbent a competitive disadvantage *a priori* and, for that reason, does not call for compensatory regulatory intervention merely because of its existence. Empirically, the exact size of these effects and the breakpoint size of the rural area certainly need to be estimated on a case-by-case basis. While the results above were obtained with arbitrary parameters and cannot be readily used for regulatory decisions, they have shown that the relationship between consumer loyalty and the size of the area with high service costs is crucial for the welfare analysis of USO.

## V. Conclusions

The above simulation results show that consumer loyalty is a crucial factor for the profitability of postal operators. Moreover, consumer loyalty can provide an incumbent with a competitive advantage, even when forced – through uniform pricing constraint – to operate unprofitably in some areas. These results are counter-intuitive, as it is generally believed that the larger the loss-making segment, the bigger the competitive disadvantage imposed by uniform pricing is. The backward-looking nature of consumer demand, assumed in the above model, inverses this relationship. Due to consumer loyalty, an incumbent enjoys a competitive advantage unless the size of the loss-making area is not big enough to form a positive perception, or indeed, if it is too big to allow for overall profitability.

When discussing policy implications, however, it is important to be prudent. There are limits to the predictive and prescriptive abilities of ABM (discussed e.g. in Twomey and Cadman, 2002). While the ABM method undoubtedly



provides useful qualitative insights, the exact impact of specific policy changes cannot be conclusively predicted without further refinements to the model. First of all, identifying the rules governing individual behaviour is in itself a complex task, often involving arbitrary assumptions. To some extent, this problem can be solved by testing different calibrations of the above model, which this paper has partially done. Second, in order to closely reflect reality, ABM simulations should be based on adequate empirical data in terms of defining individual rules as well as specifying relevant parameters.

What recommendations can be made, therefore, for further research? First, at least partial empirical estimation of the parameters used in the above model could improve its robustness and predictive ability. Second, further calibration refinements could be made. The model is flexible enough to allow for different kinds of extensions (e.g. 'business' and 'retail' customers, or different kinds of services). Moreover, interactions between consumers, such as synchronisation of decision-making or knowledge sharing, could be introduced. Finally, the issue of which mechanism is preferable for compensating the net cost of USO was left beyond the scope of this analysis. One could extend it to, for example, the implications of different ways of compensation or to a bargaining process over the net cost between a USO provider and the respective regulatory authorities.

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